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Effects of Motor Skill Intervention on Developmental Coordination Disorder: A Meta-Analysis

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The purpose was to determine whether evidence exists in published research from 1970 to 1996 to support motor skill intervention for children with developmental coordination disorder (DCD) or equivalent conditions. The following questions were addressed: (a) Which (if any) of three theoretical approaches to motor skill interventions is supported by evidence? (b) How do age of participants, research design, intervention setting, and intervention duration affect motor outcomes? (c) What are the results of meta-analysis? Twenty-one relevant studies were identified, and 13 (all that reported means and standard deviations) were subjected to meta-analysis. Findings indicated that motor skill intervention is most effective when applied with (a) children with DCD over age 5, (b) the specific skill theoretical approach, (c) intervention conducted in a group setting or as a home program, and (d) intervention frequency of at least 3 to 5 times per week. No clear findings emerged in regard to other variables.

Some children lack the motor competence necessary to cope with the demands of everyday living. According to the *Diagnostic and Statistical Manual of Mental Disorders, DSM-VI* (American Psychiatric Association, APA, 1994), these children are diagnosed as having a developmental coordination disorder (DCD). In 1994, an international meeting on children and clumsiness held in London, Ontario, Canada, resulted in a consensus statement regarding the nomenclature, description, definition, assessment, and management of children with mild motor problems (Polatajko, Fox, & Missiuna, 1995a). Shortly before this meeting, the *Adapted Physical Activity Quarterly* published a special issue entitled "Developmental Coordination Disorder." Ten papers appeared in the issue edited by S.E. Henderson (1994), representing a diversity of approaches, since no single perspective reveals the entire picture of DCD.

DCD is a motor performance impairment that is not explicable by the child's age, intellect, or other diagnosable neurological or psychiatric disorders. A high

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incidence of associated problems in a wide range of functions typically occurs with DCD (Polatajko et al., 1995a). If mental retardation is present, the motor difficulties are in excess of those usually associated with it (APA, 1994). Some of the children with these motor problems may previously have been diagnosed as having minimal brain dysfunction (Clemmens, 1961); or dysfunction of attention, motor control, and perception (Gillberg, 1991); or motor impairment (MI; Henderson & Hall, 1982); or as being clumsy (C; Hulme & Lord, 1986); or as having sensory integration dysfunction (SID; Ayers, 1972; Fisher, Murray, & Bundy, 1991). For purposes of meta-analysis, participants in the studies were categorized as DCD, C/MI, or SID, depending on either the terminology used or the diagnostic criteria described. To simplify writing, the term DCD is used in this manuscript to encompass equivalent conditions described by many names.

In some of these children, the problems are still present in adolescence (Cantell, Smyth, & Ahonen, 1994; Gillberg & Gillberg, 1989; Gillberg, Gillberg, & Groth, 1989; Hellgren, Gillberg, Gillberg, & Enerskog, 1993; Losse et al.,1991). Cantell et al. (1994) reported a follow-up of children who were diagnosed at age 5 as having delayed motor development. Ten years later, 46% of the members of the early motor delay group still differed from the control group in motor and perceptual performance.

Schoemaker and Kalverboer (1994b) reported results suggesting that children who are clumsy are more introvert than those without movement problems, judge themselves to be less competent both physically and socially. Intervention for these children should be holistic, multifaceted, and individualized to meet unique needs. Intervention can incorporate (a) appropriate therapeutic techniques; (b) the teaching of coping strategies; (c) consultation with teachers, caregivers, parents, and others; (d) and modification of the school environment (Polatajko et al., 1995a).

Theoretical Approaches on Motor Skill Interventions

Motor skill intervention is believed to remediate children's motor problems (Miyahara, 1996; Sherrill, 1998; Sigmundsson, Pedersen, Whiting, & Ingvaldsen, 1998; Sugden, & Chambers, 1998; Willoughby & Polatajko, 1995). Clinical programs designed specifically to treat children with DCD are few (Schoemaker, Hijlkema, & Kalverboer, 1994a). In the present study, interventions are grouped according to three theoretical approaches.

General Abilities (GA) Approach

Methods based on this approach are generally called neurodevelopmental treatment (Bobath & Bobath, 1984) or perceptual-motor training (Cratty, 1981; Hallahan & Cruickshank, 1973; Kephart, 1971; Sherrill, 1998). The GA approach implies that age-appropriate reflexes, postural reactions, and perceptual-motor abilities all underlie functional motor skills and conceptual development. Intervention consists mainly of facilitation of balance and other physical abilities and training in specific perceptual and motor tasks. Researchers have reviewed studies using neurodevelopmental treatment (Ottenbacher et al., 1986; Royeen & DeGangi, 1992) and perceptual-motor training (Kavale & Mattson, 1983). Findings indicate many and confounding variables.

Sensory Integration (SI) Approach

This approach is associated mainly with the sensory integrative therapy method (Ayers, 1972; Fisher et al., 1991; Ottenbacher, 1991) and kinesthetic training (Laszlo & Bairstow, 1983). In this approach, it is assumed that development of cognition, language, academic, and motor skills depend on sensory integrative ability. Children with sensory-motor problems are believed to be inadequately oriented to their physical environment and need help in making adaptive responses to improve the brain process and to organize sensory input. Provision of proprioceptive, tactile, and vestibular stimulation requires activities that consist of full body movements and training in specific perceptual and motor skills. The possible gains from this kind of intervention have been investigated in children with a wide range of problems, but no clear improvement has been found (Hoehn & Baumeister, 1994; Ottenbacher, 1991; Polatajko, Kaplan, & Wilson, 1992; Sims, Henderson, Hulme, & Morton, 1996a).

Specific Skills (SS) Approach

Methods based on this approach include task-specific instruction (Larkin, Hoare, & Smith, 1989; Revie & Larkin, 1993), the knowledge-based approach (Wall, McClements, Bouffard, Findlay, & Taylor, 1985), the effort-centered approach (Laban & Lawrence, 1947), and the cognitive-affective approach (Sims et al., 1996b). The SS approach is based on the assumption that specific motor control and motor learning processes underlie skilled movement. These processes all involve the interaction of genetic and experiential factors (Wall et al., 1985). Most physical education texts recommend the SS approach. The key to successful motor training programs is combinations of correctly performed practice of functional skills, appropriate repetition, and sufficient guidance and time to facilitate skill retention and generalization. The individual must be an active, not passive, participant in the training process (Croce & DePaepe, 1989; Gentile, 1989).

Purpose

The purpose of this study was to determine whether evidence exists to support motor skill intervention for children with DCD. The following questions were addressed: (a) Which (if any) of the three theoretical approaches to motor skill interventions is supported by evidence? (b) How do age of participants, research design, intervention setting, and intervention duration affect motor outcomes? (c) What are the results of meta-analysis?

Method

Selection of Primary Sources

The literature pertaining to motor skill interventions was surveyed from 1970 to 1996. The computer search was carried out in five databases: Educational Resources Information Center (ERIC), Cinahl, Medline, PsychInfo, and SPORT Discus (SIRC/CDS). Studies selected for review satisfied the first three criteria, as follows. Studies included in the meta-analysis also had to satisfy the fourth criterion.

1. The population of interest was children identified as having DCD or motor problems consistent with DCD. Before 1994, the population of interest was generally identified as clumsy, motor impaired, or physically awkward, or as children having sensory integrative dysfunction (see Table 1). Standardized tests were used to identify research participants and sometimes also a two-step selection procedure (Schoemaker et al., 1994a). Children met the criteria of (a) average intelligence/ no academic delay, (b) normal neurology, and (c) normal vision and hearing. Normal neurology could either be clearly stated (i.e., Polatajko, Law, Miller, Schaffer, & McNab, 1991) or specified by noting that medical records indicated no known neurological or other medical condition that prevented participation (Sims et al., 1996b).
2. All studies using an experimental research design with at least one control group or single subject design were selected.
3. The effects of a motor skill intervention were reported in a published research study.
4. Means and standard deviations were reported for experimental and control groups. These were needed for the meta-analysis.

Table 1 was developed to present information concerning the experimental studies selected for analysis: researchers, terminology, participants' criteria, research design, statistically significant difference in outcome, and whether mean and standard deviation were reported. The studies are presented in order of year of publication, with a distinction made between the studies published before and after the International Consensus Meeting on Children and Clumsiness held in 1994 in London, Ontario, Canada (Polatajko et al., 1995a). Twenty-one studies fulfilled the first three criteria (see Table 1). Before 1994, only two thirds of the criteria for a DCD diagnosis listed by the American Psychiatric Association (1994) were used in more than half of the studies. In studies published after 1995, all three criteria were met. In all studies except two (Bishop & Horvat, 1984; Marchiori, Wall, & Bedingfield, 1987), a statistical analysis was reported. In accordance with previous review studies (Parrette & Hourcade, 1984; Royeen & DeGangi, 1992) and meta-analysis (Chanias, Reid, & Hoover, 1998; Miyahara, 1996), the motor skill intervention studies were examined in terms of their theoretical approach, age, number and gender of participants, research design, intervention setting and duration, dependent measures, and significant difference in outcome. Means and standard deviations for groups were reported for only 13 of the 21 studies.

Selection of Method

A meta-analysis was selected to analyze related research. A coding scheme for variables in each study was formulated, as follows.

1. Theoretical approach of motor skill intervention was coded as GA (general ability) approach, SI (sensory integration) approach, SS (specific skill) approach, or a combination of the theoretical approaches.
2. Age in years was coded as 3 to 5 years or 6 to 13 years. Gender was coded as m = male or f = female.
3. Research design was coded according to how assignment of participants to groups had been performed: R = participants were randomly assigned to

Table 1 Information Available in Experimental Studies Selected for Analysis

	Terminology			Participant criteria				Study information		
Researcher	DCD	Clumsy/ MI	SID	Average IQ	Normal neurology	Normal vision and hearing	No academic delay	Research design	Sign diff.	*M* (*SD*) reported for Dep meas.
Studies before 1994 (*N* = 14)										
Allen, 1971	—	x	—	x	—	—	—	MNR	Y	x
Platzer, 1976	—	x	—	—	—	—	—	R	—	x
Horvat, 1982	—	x	—	—	—	—	x	R	Y	x
Bishop & Horvat, 1984	—	x	—	x	—	x	—	SSD	—	—
Kernahan & Fillary, 1986	—	x	—	—	—	x	—	R	Y	—
Marchiori et al., 1987	—	x	—	—	—	—	—	MNR	—	—
Watter & Bullock, 1987	—	x	—	—	—	—	x	R	Y	x
Laszlo et al., 1988	—	x	—	—	x	x	—	MR	Y	—
Humphries et al., 1990	—	—	x	x	x	x	x	R	Y	x
Polatajko et al., 1991	—	x	x	x	x	—	x	R	—	x
Humphries et al. I, 1992	—	—	x	x	x	x	x	R	Y	x
Wilson et al., 1992	—	x	—	x	x	x	x	R	—	x
Humphries et al. II, 1993	—	—	x	x	x	x	x	R	—	x
Revie & Larkin, 1993	—	x	—	—	—	—	—	MR	Y	x

(*continued*)

Table 1 (*continued*)

Researcher	Terminology			Participant criteria				Study information		
	DCD	Clumsy/ MI	SID	Average IQ	Normal neurology	Normal vision and hearing	No academic delay	Research design	Sign diff.	*M* (*SD*) reported for Dep meas.
Studies 1994 and after ($N = 9$)										
Davies & Gavin, 1994	—	x	—	—	—	—	—	MNR	—	x
Lockhart & Law, 1994	—	x	—	x	x	x	—	SSD	Y	—
Schoemaker et al., 1994a	x	x	—	—	x	—	x	MNR	Y	x
Jarus & Gol, 1995	—	—	x	—	—	x	—	R	Y	—
Polatajko et al., 1995b	x	—	—	x	x	x	—	R	Y	x
Sims et al. I, 1996a	x	x	—	x	x	—	—	MR	—	x
Sims et al. II, 1996b	x	x	—	x	x	—	—	MR	Y	x

Notes. Terminology: DCD = developmental coordination disorder; MI = motor impairment; SID = sensory integrative dysfunction. Research Design: R = participants randomly assigned; MR = participants matched and then randomly assigned; MNR = participants matched but not randomly assigned; SSD = single subject design. Sign diff.: Y = yes significant difference in outcome reported. Dep meas. = dependent motor measure.

experimental or control group; MR = participants were matched on key variables and then randomly assigned; MNR = participants were matched on key variables, but not randomly assigned; or SSD = single subject design. Research design for the meta-analysis was also coded as (a) between-subject designs with pretest and posttest, (b) between subject designs without pretest and posttest, and (c) within subject designs.

4. Intervention setting was coded as SmGr = small group (performed by a teacher); HoPr = home program (performed by parents); or 1:1 (one-to-one setting performed by a physical therapist or an occupational therapist).
5. Intervention duration included length coded as less than 3 months or 3 months or more, and frequency coded as less than 3/week or 3-5/week.
6. Significant difference in outcome after motor skill intervention was coded as Y (yes) or N (no), according to whether the first or only experiment in the study had this result.

Table 2 was developed to provide a summary of researcher, theoretical approach, age, number and gender, research design, intervention, dependent measure, and significant difference. Table 2 also presents the effect size of dependent measures (ES of DM) and the mean ES of each experiment (MES of Exp). Effect size (ES) values were calculated as follows.

Conducting the Meta-Analysis

Means and standard deviations were reported for only 13 studies (see Table 2); therefore, the meta-analysis could be calculated only on the experiments in these studies. The difference between means of the two groups was divided by the group's standard deviation pooled. The pooled standard deviation was used, since the number of children in the groups compared in each study was not the same, and the group variances for the dependent variables did not vary much (Rosenthal, 1994). The pooled standard deviation (SDp) was calculated using the following formula: $SDp = (Nexp - 1)(SDexp)^2 + (Ncon - 1)(SDcon)^2 / (Nexp + Ncon - 2)$. The methodology for estimating ES used by Chanias et al. (1998) was used in the present study as well.

In between-subject designs, with pretest and posttest, the ES was calculated by the mean difference between the experimental group's pretest and posttest change and the control group's pretest and posttest change (Becker, 1988). The mean difference of the control group was subtracted from the mean difference of the experimental group and then divided by the pooled standard deviation.

In between-subject designs, without pretest and posttest, ES was calculated using the methodology by Hedges and Olkin (1985). The mean score of the experimental group (Mexp) was subtracted from the mean score of the control group (Mcon), and divided with the pooled standard deviation $(ES = Mexp - Mcon / SDp)$.

Within-subject designs were included when a group of children had been studied, not a single subject. ES in within-subject designs was calculated using the formula described by Becker (1988): $(ES = M\ post - M\ pre / SD\ pre)$.

Sometimes a higher score and sometimes a lower score on a test indicated improvement. To have a positive ES indicating a positive intervention effect, and a negative ES indicating a negative intervention effect, the experimental group's mean could in the formula in some cases be subtracted from the control group's mean (Thomas & French, 1996).

Table 2 An Overview of All Studies Selected for Analysis (1971-1996)

Researcher	Theoretical approach	Age, years	N/ gender	Research design	Intervention	Dependent measures	Sign diff.	ES of DM $N = 45$	MES of Exp. $N = 18$
Studies before 1994 (14 studies, 21 experiments)									
Allen, 1971	SS	6-9	6 m	MNR B-S with	EXP: SmGr. PE with effort. 3 months, 14 sessions (2/w) 40 min.	(1) STOTT	Y	2.08	2.08
			6m		CON: SmGr. Regular PE. Length: see 1.				
Platzer, 1976	GA+SI	4-5	5 m-8 f	R B-S without	EXP: SmGr. PM training (OT). 1 1/2 month, 50 sessions (5/w), 30 min.	(2) Cratty GMT	N	0.20	0.20
			7 m-6 f		CON: No training.				
Horvat, 1982	GA	7-9	5 m	R B-S with	EXP I: HoPr. Balance. 2 1/2 month, 30 sessions (3/w), 30 min.	(2) Cratty GMT	Y	2.51	2.51
			5 m		CON: No training.				
	GA		5 m		EXP II: HoPr. Fine motor.	(2) Cratty GMT	N	0.37	0.37
			5 m		Length: see 1. CON: No training.				
Bishop & Horvat, 1984	GA	8	1 m	SSD —	HoPr. Balance. 1 1/2 month, 20 sessions (3/w), 30 min.	(3) Balance task	N	—	—
Kernahan & Fillary, 1986	GA	5-8	41 m/f	R B-S with	EXP: SmGr. PM training. 2 months, 40 sessions (5/w), 30-45 min.	(4) Arnheim-Sinclair Battery.	Y	0.12	0.21
			41 m/f		CON: No training.	(5) Bender Purdue Reflex Test		0.30	

Marchiori et al., 1987	SS	6-8	2 m	MNR B-S with	EXP: HoPr. Hockey slap shot. 1.200 shots.	(6) Hockey slap shot	N	—	—
			2 m		CON: HoPr. Hockey slap shot. Length: see 1.				
Watter & Bullock, 1987	GA	5-13	20 m-8 f	R B-S with	EXP: I:1 and HoPr. Sensory-motor techniques (PT). 6 months, 6 sessions (1/month).	(7) Neurodevel-opmental Test.	Y	2.19	2.19
			19 m-7 f		CON: No training.				
Laszio et al., 1988	SI	7-11	9	MR B-S with	EXP.I: 1:1. Kinesthetic, spatial, temporal training. 2 weeks, 10 sessions, 20 min.	(8) TOMI (9) Perceptual-Motor Abilities Test (PMAT)	Y	—	—
			9		CON: Remedial training. 2 weeks, 9 sessions, 15 min.				
	SI		9		EXP.II: 1:1. Kinesthetic training. 2 weeks, 8 sessions, 12 min.		Y	—	
			9		CON: see above.				
	SI		10		EXP.III: 1:1. Spatial and temporal training. 2 weeks, 9 sessions, 17 min.		N	—	
			9		CON: see above.				
Humphries et al., 1990	SI	6-9	7 m-3 f	R B-S with	EXP.I: 1:1. SI therapy (OT). 5 1/2 month, 24 sessions (1/w), 60 min.	(10) BOTMP (11) SCSIT (12) SCPRNT	Y	0.86 0.43 0.26	0.55
			—		CON: No training.	(13) VMI		0.63	
	GA		7 m-3 f		EXP.II: 1:1. PM training. (OT). Length: see 1.	(10) BOTMP (11) SCSIT	N	0.70 –0.14	0.54
			—		CON: No training.	(12) SCPRNT (13) VMI		0.81 0.78	

(continued)

Table 2 (*continued*)

Researcher	Theoretical approach	Age, years	N/ gender	Research design	Intervention	Dependent measures	Sign diff.	ES of DM $N = 45$	MES of Exp. $N = 18$
Studies before 1994 (14 studies, 21 experiments)									
Polatajko et al., 1991	SI	6-8	35 m/f	R B-S with	EXP: 1:1. SI therapy (OT). 6 months, 26 sessions (1/w), 60 min.	(10) BOTMP	N	–0.03	–0.03
			32 m/f		CON: 1:1. PM training (OT). Length: see 1.				
Humphries et al. I, 1992	SI	6-9	32 m-3 f	R B-S with	EXP.I: 1:1. SI therapy (OT). 8 months, 72 sessions (3/w), 60 min.	(10) BOTMP (14) Observation (11) SCSIT	Y	0.02 0.64 0.33	0.23
			29 m-4 f		CON: No training.	(12) SCPRNT (13) VMI		0.10 0.08	
	GA		32 m-3 f		EXP.II: 1:1. PM training (OT). Length: see 1.	(10) BOTMP (14) Observation	Y	0.50 0.29	0.30
			29 m-4 f		CON: No training.	(11) SCSIT (12) SCPRNT (13) VMI		0.16 0.33 0.21	
Wilson et al., 1992	SI	5-9	14 m/f	R B-S with	EXP: 1:1. SI therapy (OT). 12 months, 75-80 sessions (2/w), 50 min.	(10) BOTMP (14) Observation (11) SCSIT	N	–0.24 0.09 0.03	0.10
			15 m/f		CON: Tutoring (T). Length: see 1.	(12) SCPRNT		0.52	
Humphries et al. II, 1993	SI	6-9	32 m-3 f	R B-S with	EXP.I: 1:1. SI therapy (OT). Length: see Humphries 1992.	(14) Observation (11) SCSIT (12) SCPRNT	Y	—	—

			29 m-4 f		CON: No training.				
	GA		32 m-3 f		EXP.II: 1:1 PM training (OT). Length: see Humphries 1992.	(14) Observation (11) SCSIT (12) SCPRNT	N	—	
			29 m-4 f		CON: No training.				
Revie & Larkin, 1993	SS	5-9	11 m/f	MR B-S with	EXP.I: SmGr. Task treatment I. 1 month, 8 sessions (2/w), 10 min.	(15) Distance throw (15) Distance hop	Y	0.75 0.39	0.57
			10 m/f		CON: SmGr. Task treatment II. Length: see 1.				
	SS		10 m/f		EXP.II: SmGr. Task treatment II. Length: see 1.	(15) Target kick (15) Volley ball bounce	Y	0.90 2.56	1.73
			11 m/f		CON: SmGr. Task treatment I. Length: see 1.				
Studies 1994 and after (4 studies, 9 experiments)									
Davies & Gavin, 1994	GA+SI	3-5	10	MNR B-S with	EXP: 1:1. SI (OT) and ND therapy (PT). 7 months, 120 sessions (2/w), 30 min.	(16) Peabody Developmental Motor Test	N	–0.06	0.07
			8		CON: SmGr. group/ consultation (OT/PT). 7 months, 60 sessions (4/w), 30 min.	(17) Vineland Adaptive Behavior Scale		0.13	
Lockhart & Law, 1994	SS	9-11	4 m	SSD —	1:1 and HoPr combined. Writing (OT). 2 months, 5 sessions (1/2/w), 60 min.	(18) Letter writing	Y	—	—
Schoemaker et al., 1994a	GA	6-9	17 m/f	MNR B-S within	EXP: 1:1. PM training (PT). 3 months, 24 sessions (2/w), 45 min.	(8) TOMI	Y	0.83	0.83
			18 m/f		CON; No training.				

(continued)

Table 2 (*continued*)

Researcher	Theoretical approach	Age, years	N/ gender	Research design	Intervention	Dependent measures	Sign diff.	ES of DM $N = 45$	MES of Exp. $N = 18$
Jarus & Gol, 1995	GA+SS	5-7	27 m/f	R B-S with	EXP: 1:1. Upper extremity kinesthetic stimulation (OT). 30 trials.	(19) Target throwing	Y	—	—
			27 m/f		CON: 1:1. Lower extremity kinesthetic stimulation (OT). Length: see 1.				
Polatajko et al., 1995b	GA	7-12	26 m/f	R B-S with	EXP.I: 1:1. Kinesthetic (POR) training (OT). Length: 1 month, 12 sessions (2-3/w), 20 min.	(20) KST (11) SCSIT (8) TOMI (13) VIM	Y	0.30 0.12 0.07 0.25	0.19
			24 m/f		CON: No training.				
	GA+SI		24 m/f		EXP.II: 1:1. SI therapy/PM training (OT). Length: 2 months, 24 sessions (2-3/w), 45 min.	(20) KST (11) SCSIT (8) TOMI (13) VIM	N	0.05 –0.15 –0.02 0.05	–0.02
			24 m/f		CON: No training.				
Sims et al., 1996a	SI	8-9	7 m-3 f	MR B-S with	EXP: 1:1. Kinesthetic training. 1/2 month, 10 sessions (5/w), 20-25 min.	(21) Fine motor task (20) KST (8) TOMI (22) PEST	N	—	—
			7 m-3 f		CON: No training.				

Sims et al., 1996b	SI+SS	8-9	12 m/f	MR B-S with	EXP.I: 1:1. Kinesthetic training. 1/2 month, 10 sessions (5/w), 20-25 min.	(21) Fine motor task (8) TOMI	Y	—	—
			12 m/f		CON: No training.				
	GA+SS		12 m/f		EXP.II: 1:1. Cognitive-affective training. Length: see 1.	(21) Fine motor task (8) TOMI	Y	—	
			12 m/f		CON: No training.				

Notes. Theoretical approach: GA approach = General Abilities approach, SI Approach = Sensory Integrative approach, SS approach = Special Skills approach. N/gender: Number and gender of children included in each group; m = male, f = female. Research design: R = participants were randomly assigned, MR = participants were matched on key variables and then randomly assigned, MNR = participants were matched on key variables, but not randomly assigned, SSD = single subject design. Group comparison: B-S with = between-subjects design with pretest and posttest, B-S without = between-subject design without pretest, within = within-subject design. Intervention: SmGr = Small group provided by a teacher, HoPr = Home program provided by a parent, 1:1 = individual training provided by an OT = Occupational therapist or PT = Physical therapist. Dependent measures: motor measures used in experiments. References: (1) Stott, D.H., Moyes, F.A., & Henderson, S.E. (1972); (2) Cratty, B.J. (1974); (3) Bishop, P. & Horvat, M. (1984); (4) Arnheim, D.D. & Sinclair, W.A. (1979); (5) Bender, M.L. (1976); (6) Marchiori, G., Wall, A. & Beddingfield, W. (1987); (7) Burns, Y.R., & Watter, P. (1974); (8) Stott, D.H., Moyes, F.A., & Henderson, S.E. (1984); (9) Laszio, J.I., & Bairstow, P.J. (1985a); (10) Bruininks, R.H. (1978); (11) Ayers, A.J. (1980); (12) Ayers, A.J. (1975); (13) Beery, K.E. (1982); (14) Dunn, W. (1981); (15) Revie, G., & Larkin, D. (1993); (16) Folio, M.R., & Fewell, R.R. (1983); (17) Sparrow, S.S., Balla, D.A., & Cicchetti, D.V. (1984); (18) Lockhart, J., & Law, M. (1994); (19) Jarus, T., & Gol, D. (1995); (20) Laszlo, J.I., & Bairstow, P.J. (1985b); (21) Sims, K., Henderson, S.E., Hulme, & Morton, J. (1996a); (22) Taylor, M.M. & Creelman, C.D. (1967). Sign. diff: significant difference in outcome reported Y = Yes, N = No. ES of DM: effect size of each dependent motor measure ($N = 45$). MES of Exp.: mean effect size of each experiment ($N = 18$).

ES is positively biased in small samples (Hedges, 1981). A virtually unbiased estimate of ES was obtained by multiplying the ES by the correction factor given in the following formula (Thomas & Nelson, 1996, p. 299): $c = 1 - (3 / 4m - 9)$, where $m = Nexp + Ncon - 2$ when a pooled standard deviation is used. Each ES was corrected before averaging or further analysis.

The 13 studies containing the data necessary to calculate ES were categorized by research design (see Table 2), as follows: (a) 11 between-subject designs with pretest and posttest (B-S with), (b) one between-subject design without pretest and posttest (B-S without), and (c) one within-subject design (within). ES values were calculated only for the most powerful experiments in each study, namely when a trained group was compared with an untrained group. If no such control group existed, the ES was calculated for a trained experimental group compared with a control group receiving another type of intervention. One to two experiments could then exist in each study.

In Table 2 the calculation of ES of dependent measure (ES of DM) is presented. To help readers understand this calculation, we explain one study (Allen, 1971) with a between-subject design, (ES = Mexp –Mcon/ SDpooled), ES = 12.47 – 5.17/ 3.25 = 2.25. ES was then multiplied by correction factor 0.926, which resulted in ES = 2.08. In the study by Allen (1971) the ES of DM was the same as the MES of Exp. because the researcher used only one dependent motor measure (DM). This was also the fact in the studies by Platzer (1976), Horvat (1982), Watter and Bullock (1987), Polatajko et al. (1991), and Schoemaker et al. (1994a).

The MES of Exp. was reported for the rest of the studies in Table 2. The MES was calculated as the mean of all ES values of dependent measures (DM) in an experiment. The meta-analysis was based on a total of 45 ES values, one for each dependent measure (ES of DM). The ES of DM in each experiment resulted in a total of 18 MES values (see Table 2).

All MES of Exp. were finally used to calculate the mean main ES among various coding characteristics (see Table 3). The calculation is here exemplified by the coding characteristic Theoretical approach/ General ability. For this characteristic, studies yielded a total of 9 MES of Exp: 2.51 + 0.37 + 0.21 + 2.19 + 0.54 + 0.30 + 0.83 + 0.19 - 0.02 /9. The coding characteristic Theoretical approach/ General ability resulted in a mean main ES of 0.71.

Results and Discussion

Table 2 presents information on all 21 studies selected, whereas Table 3 presents the findings of the 13 studies in the meta-analysis. Some of the 13 studies included effects of motor skill intervention using more than one intervention and under more than one condition. Hence the number of ES values ($N = 18$) calculated exceeded the number of studies. Thus, 18 mean ES values, one for each experiment (Table 2, MES of Exp.) were calculated for most of the coding characteristics. However, 45 mean ES, one for each dependent measure, were calculated for the coding characteristics dependent measure/ theoretical approach. In Table 3 the mean main ES across coding characteristics for each variable are presented to permit us to make comparisons. Following are answers to research questions that guided the present study.

Table 3 Mean Main Effect Size for Each Coding Characteristic Calculated on (MES) in Each Experiment (N = 18)

Coding characteristics	N	Mean main ES
Theoretical approach	MES of Exp.	
GA = General ability	9	0.71
SI = Sensory integrative	4	0.21
SS = Specific skill	3	1.46
GA + SS	1	0.20
GA + SI	1	0.07
Age, years		
3 to 5 years	2	0.14
6 to 13 years	16	0.77
Research design		
R = randomly assigned	13	0.56
MR = matched and randomly assigned	2	1.15
MNR = matched, but not randomly assigned	3	0.99
SSD = Single subject design	—	No data for ES calculation
Intervention setting		
SmGr = Small group	5	0.96
HoPr = Home program	2	1.41
1:1 = one-to-one setting	11	0.45
Intervention length		
Less than 3 months	8	0.72
3 months or more	10	0.69
Intervention frequency		
Less than 3/week	11	0.60
3-5/week	7	0.86

Theoretical Approach

Which (if any) of the three theoretical approaches to motor skill interventions is supported by evidence? Experiments evaluating motor skill intervention with the specific skill (SS) theoretical approach yielded the highest mean main ES (1.46). The GA approach yielded 0.71, whereas experiments using combined approaches and the sensory integration (SI) approach yielded the lowest (0.07, 0.20, and 0.21). This implies that the activities used when working with children with clumsiness should be more task-specific, as transference of learning to similar performance areas is often difficult for this population (Sellers, 1995). Therapists need to dispel the notion of directly improving academic, language, cognitive (Humphries, Wright, Snider, & McDougall, 1992), and motor (Hoehn & Baumeister, 1994) performance by training based on the SI approach. These findings are consistent with the findings in the meta-analysis that Miyahara (1996) performed on three studies.

However, these observations should be accepted with reservation because many factors besides theoretical approach affect findings.

Age

How does age affect outcomes? Experiments evaluated in the meta-analysis concerned participants ages 3 to 13 (see Table 2). In most studies, the participants were in primary or elementary grades. A difference is noted in Table 3 when comparing the mean main ES in the coding characteristic age/ years. Experiments involving children 6 to 13 years old yielded a mean main ES of 0.77 compared to a mean main ES of 0.14 in experiments conducted on children 3 to 5 years old. There were two experiments conducted on the latter group; in these, the GA and SI approaches were used.

Research Designs

How does research design affect outcomes? The single subject design (SSD) does not permit effect size calculation, and studies with this design were not included in the meta-analysis. In the experiments included, participants were randomly assigned (R), or matched on key variables and then randomly assigned (= MR), or matched but not randomly assigned (MNR). In some research methods textbooks, the MNR design is not considered a good design (Brink & Wood, 1989). The results in Table 3 show that in research designs where children were randomly assigned (R) to groups, the mean main ES was (0.56). When the children were matched and randomly assigned (MNR), the mean main ES was (1.15). All types of assignment of participants seem to support intervention, but the result stresses the need for a more rigorous assignment.

Intervention Setting

How does intervention setting affect outcomes? Administration of intervention in a one-to-one-setting (1:1) was most frequently used. This setting yielded lowest mean main ES (0.45) compared to administration in a small group (SmGr; 0.96), or in a home program (HoPr; 1.41). Support for intervention setting in an experiment does not merely depend on the administration. The SS approach was not used in any of the 11 experiments evaluating a one-to-one setting. Children with DCD seem to have heterogeneous problems (Hoare, 1994; Kaplan, Wilson, Dewey, & Crawford, 1998); therefore, it is possible that different children may need and benefit from different interventions. Children who received intervention in a one-to-one setting may have had more severe motor difficulties. To facilitate comparison, the diagnostic criteria for children with DCD should be described in detail (Barnett, Kooistra, & Henderson, 1998; Henderson & Barnett, 1998; Henderson & Hall, 1982; Hoare, 1994; Sellers, 1995). Also, in nine out of the 11 studies using a one-to-one setting, a random assignment of participants was used.

Intervention Duration

How does intervention duration affect outcomes? Concerning length of intervention, mean main ES was similar (0.72 and 0.69) irrespective of whether the intervention lasted less than 3 months or 3 months or more. Frequency of intervention coded as 3 to 5 times per week yielded higher mean main ES (0.86) than the less frequent intervention did (0.60). An intervention based on the SS theoretical approach was not used in any study with a frequency of 3 to 5 times per week. Length and frequency of interventions was not related to the theoretical approach of the intervention.

Conclusion

It is concluded, based on the meta-analysis, that there is evidence to support motor skill intervention for children with DCD who are older than 5 years of age. Of the three theoretical approaches, the SS theoretical approach is recommended. An intervention conducted in a group setting or in a home program, with intervention frequency of at least 3 to 5 times per week, is recommended. Findings with regard to intervention duration are not clear. This study has also shown the need for future research on well-defined subgroups of children with DCD.

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Note. This reference list includes citations in both text and tables.

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